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Innovation nodes in technological higher education: determining factors for triple helix articulation

Nodos de innovación en la educación superior tecnológica: factores determinantes para la articulación de la triple hélice

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Abstract

This study analyzes the factors justifying the implementation of an innovation node at the Technological Institute of Puebla (ITP) to strengthen knowledge and technology transfer within the National Technological of Mexico (TecNM). Using a descriptive quantitative approach, 346 students and professors were surveyed from 254 projects belonging to 147 Technological Institutes across the country that reached the national phase of InnovaTecNM 2023. Results reveal that funding and technical advisory are priority needs (32.37% each), followed by the demand for specialized laboratories (36.05%) and intellectual property training. Additionally, 62.43% of participants expressed willingness to receive institutional technical-commercial guidance. Furthermore, the need for training in financial analysis, market research, and legal structure was identified to consolidate viable business models. The findings, discussed under the Triple Helix model, confirm that the gap between research and the market demands permanent institutional structures. It is concluded that the innovation node serves as a key coordinating mechanism to increase the technological maturity of projects and promote technology-based entrepreneurship with a national impact.

Keywords: Technology transfer; Technological entrepreneurship; Intellectual property; Innovation node; Triple helix; Technological maturity.

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Resumen:

El presente estudio analiza los factores que justifican la implementación de un nodo de innovación en el Instituto Tecnológico de Puebla (ITP) para fortalecer la transferencia de conocimiento y tecnología en el Tecnológico Nacional de México (TecNM). Mediante un enfoque cuantitativo descriptivo, se encuestó a 346 estudiantes y docentes de 254 proyectos pertenecientes a 147 delegaciones de Institutos Tecnológicos del país que alcanzaron la fase nacional de InnovaTecNM 2023. Los resultados revelan que el financiamiento y el asesoramiento técnico son necesidades prioritarias (32.37 % cada uno), seguidos por la demanda de laboratorios especializados (36.05 %) y capacitación en propiedad intelectual. El 62.43 % de los participantes mostró disposición para recibir acompañamiento técnico-comercial institucional. Asimismo, se identificó la necesidad de formación en análisis financiero, estudio de mercado y estructura legal para consolidar modelos de negocio viables. Los hallazgos, discutidos bajo el modelo de la Triple Hélice, confirman que la brecha entre investigación y mercado exige estructuras institucionales permanentes. Se concluye que el nodo de innovación es un mecanismo articulador clave para incrementar la madurez tecnológica de los proyectos y promover el emprendimiento de base tecnológica con impacto nacional.

Palabras clave: Transferencia tecnológica; emprendimiento tecnológico; Propiedad intelectual; Nodo de innovación; Triple hélice; Madurez tecnológica.

Introduction

Higher education institutions (HEIs) play a strategic role in generating scientific knowledge, advancing technological development, and educating highly skilled human capital. Despite these contributions, a persistent challenge is converting research outputs into innovations that generate tangible economic and societal value. In this context, knowledge and technology transfer has become a critical mechanism for bridging academic research and industry needs, fostering technology-based entrepreneurship, protecting intellectual property, and supporting regional economic development.

In Mexico, the TecNM has implemented several initiatives to promote technology-based entrepreneurship, among which the InnovaTecNM competition has become one of the most important. The program encourages students and faculty to develop innovative projects with potential applications in both industrial and social contexts. However, once participation in the competition ends, many projects struggle to progress beyond the proof-of-concept stage. Common barriers include limited access to funding, specialized research infrastructure, technical mentoring, intellectual property protection, and industry partnerships. Consequently, many promising innovations fail to advance toward commercialization, remaining at early stages of technological development.

Previous studies have shown that specialized institutional support structures—including Technology Transfer Offices (TTOs), business incubators, accelerators, and innovation hubs—play a key role in connecting researchers, students, industry, and government stakeholders, thereby increasing the likelihood of successful technology commercialization and strengthening regional innovation ecosystems (Etzkowitz & Leydesdorff, 2000). These organizations facilitate access to financial resources, mentoring, technological infrastructure, and collaborative networks, all of which are essential for increasing the technological maturity of research projects and narrowing the gap between laboratory research and market applications.

TecNM has developed strong research capabilities in strategic fields such as nanotechnology and semiconductor materials. Recent studies have reported the fabrication of pure semiconductor materials using different synthesis techniques (Flores-Carrasco et al., 2017; Bueno et al., 2024; Flores-Carrasco et al., 2025), the synthesis of nanoparticles for photocatalytic applications (Flores-Carrasco et al., 2021; Mora et al., 2024; Mora-Viquez et al.,

2026), and the development of doped semiconductor materials for a wide range of technological applications (Muñoz-Fernández et al., 2017; Martínez-Martínez et al., 2021; Ferreiro et al., 2023). Despite this significant scientific output, many of these research results remain confined to the laboratory and do not progress toward technology transfer or commercial exploitation. This situation underscores the need to strengthen institutional mechanisms that support intellectual property management, industry engagement, and technology scale-up. In this regard, innovation node represents a promising approach for integrating existing scientific capabilities with innovation processes that contribute to regional economic and social development.

Against this background, the present study aims to identify the factors that support the implementation of an innovation node at the ITP. The analysis is based on the perceptions of students and faculty members whose projects reached the national stage of the 2023 InnovaTecNM competition. By examining needs related to research infrastructure, funding opportunities, technical mentoring, technology transfer, and business model development, this study seeks to provide empirical evidence to inform the design of an institutional strategy that strengthens innovation capacity, enhances technology transfer, and promotes technology-based entrepreneurship across the TecNM system.

State of the Art

Innovation has evolved from traditional linear models centered primarily on scientific research toward collaborative approaches in which universities, industry, and government jointly participate in the creation, diffusion, and application of knowledge. One of the most influential conceptual frameworks is the Triple Helix model proposed by Etzkowitz and Leydesdorff (2000), which argues that knowledge-based economic development depends on continuous interaction among these three actors. Within this framework, universities are no longer viewed solely as institutions devoted to teaching and research but also as entrepreneurial organizations that actively contribute to innovation and regional development.

Within this context, technology transfer represents the process through which research outputs are transformed into industrial applications, products, and services that generate economic and societal value. According to Siegel, Waldman, and Link (2003), the effectiveness of technology transfer depends not only on institutional infrastructure but also on governance mechanisms

that facilitate collaboration among researchers, firms, and investors. Consequently, Technology Transfer Offices (TTOs) and innovation centers have become key institutional intermediaries responsible for managing intellectual property, promoting technology licensing, and supporting the creation of academic spin-offs.

The World Intellectual Property Organization (WIPO, 2023) further emphasizes that effective management of intellectual assets is a critical determinant of competitiveness in higher education institutions. Protecting research outcomes through patents, utility models, industrial designs, and copyrights enhances commercialization opportunities while creating favorable conditions for collaboration with industry. Consequently, intellectual property education and management have become essential components of institutional strategies aimed at fostering innovation and technology commercialization.

From the perspective of technology entrepreneurship, Osterwalder and Pigneur (2010) argue that the development of a robust business model is fundamental for transforming technological innovations into economically sustainable value propositions. Similarly, Blank and Dorf (2020) highlight that early market validation, continuous experimentation, and close engagement with potential users significantly reduce the uncertainty associated with the development of new technology-based products. These approaches have been widely adopted by university incubators, accelerators, and innovation centers worldwide as part of entrepreneurship support programs.

In Latin America, the literature consistently identifies several barriers to the development of university innovation ecosystems, including limited financial resources, weak university–industry collaboration, insufficient intellectual property awareness, and the absence of permanent institutional structures dedicated to technology transfer. In Mexico, although TecNM has promoted innovation and entrepreneurship through initiatives such as the InnovaTecNM competition, there remains a need to strengthen institutional mechanisms that continue supporting projects beyond the competition stage, facilitating their technological advancement, commercialization, and market entry.

Against this background, the establishment of an innovation node offers a comprehensive institutional approach that integrates specialized mentoring, technological infrastructure, intellectual property management, business incubation, and collaboration with public and

private organizations. Such a framework can strengthen knowledge and technology transfer, increase the technological maturity of innovation projects, and contribute to national economic development by promoting innovations with both commercial potential and societal impact.

Methodology

This study employed a quantitative research approach with a descriptive design to identify the needs and perceptions of students and faculty regarding the implementation of an innovation node at the ITP. In addition, the study examined the factors influencing knowledge and technology transfer within the institutional context.

Data collection was conducted during the 2023 national stage of the InnovaTecNM competition, hosted by ITP and organized by the TecNM. The event brought together 254 innovation projects submitted by 147 technological institutes from across Mexico. Projects were distributed across several strategic areas of technological innovation, including Agrifood, Electrical and Electronic Industry, Electromobility and Smart Cities, Health Services, Creative Industries, and Climate Change. According to the Mexican Ministry of Public Education (Secretariat of Public Education, 2023), the event served as a national platform for showcasing research, technological development, and innovation initiatives while promoting collaboration among students, faculty members, and academic communities from different regions of the country.

The geographic, academic, and institutional diversity of the participants provided an opportunity to capture perspectives from a wide range of contexts, recognizing that institutional environments may influence project characteristics, technological needs, and technology transfer opportunities. Consequently, the event offered a valuable setting for examining the institutional conditions required to strengthen university innovation ecosystems.

The study population consisted of 346 participants, including undergraduate and graduate students as well as faculty advisors whose projects advanced to the national stage of the 2023 InnovaTecNM competition. Surveys were administered during the event to participants from both undergraduate and graduate categories. The undergraduate sample included projects in the areas of Agrifood, Electrical and Electronic Industry, Electromobility and Smart Cities, Health Services, Creative Industries, and Climate Change. The graduate sample comprised projects in

Agrifood, Electrical and Electronic Industry, Health Services, Creative Industries, and Climate Change.

Data was collected using a structured questionnaire consisting of six single-response questions designed to assess participants' awareness of innovation node and technology transfer processes. The instrument also explored key needs related to funding, research infrastructure, technical mentoring, intellectual property management, prototype development, and business model design. Prior to full-scale implementation, the questionnaire was pilot-tested to evaluate item clarity, identify potential inconsistencies, and refine the instrument, thereby improving the reliability of the data collected.

The survey was administered electronically through the TecNM institutional (Forms) platform, enabling efficient digital data collection, streamlined data management, and reduced transcription errors. Participation was voluntary, and all responses were collected exclusively for research and academic purposes.

The data were analyzed using descriptive statistics. Frequency distributions and percentages were calculated to summarize participants' responses and identify prevailing trends. The findings were used to determine the priority factors supporting the design of an innovation node at the ITP, with the objective of strengthening technology transfer, enhancing collaboration with industry, and promoting the development of projects with higher levels of technological maturity.

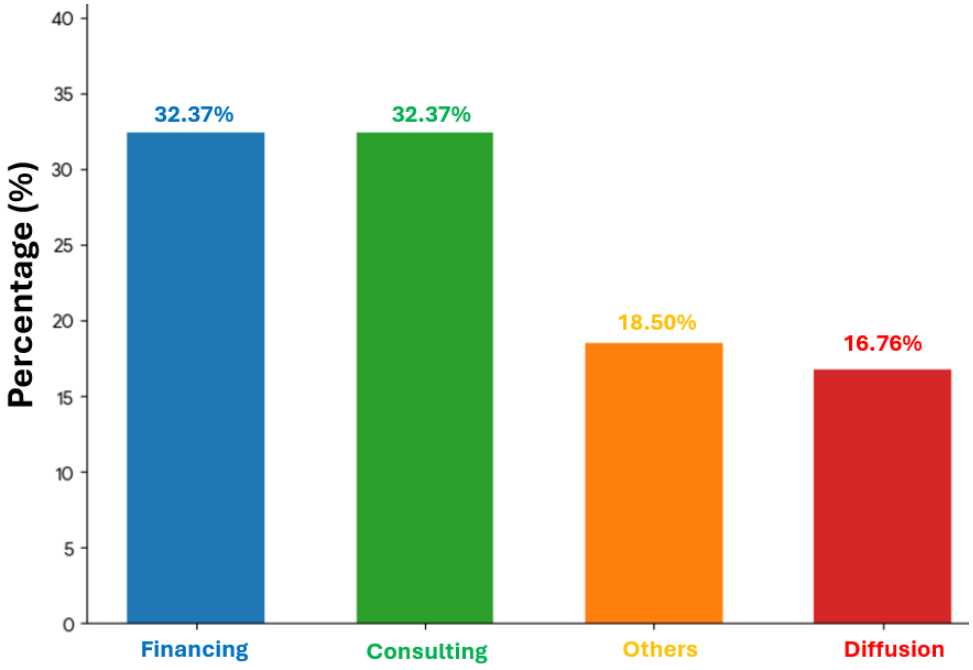
Results

The empirical findings are presented through a series of statistical figures summarizing the responses provided by the surveyed students and faculty members. These results identify the key factors supporting the proposed implementation of an innovation node and provide insights into the institutional conditions influencing knowledge and technology transfer. The analysis is based on the perceptions of students and faculty advisors whose projects advanced to the national stage of the 2023 InnovaTecNM competition.

Figure 1 presents the factors perceived as most influential in attracting entrepreneurs to an innovation node aimed at supporting projects with higher levels of technological maturity.

Funding and specialized mentoring emerged as the two highest priorities, each accounting for 32.37% of responses. Participants emphasized that access to financial resources is critical because most projects are currently financed by students themselves and, in some cases, by faculty advisors. The equally high demand for mentoring reflects the need for continuous technical and entrepreneurial support throughout the technology transfer process. The category labeled *Other* accounted for 18.50% of responses and primarily included comments related to infrastructure management and more effective use of existing institutional resources. Finally, dissemination and promotion represented 16.76% of responses, suggesting that participants perceive limited institutional visibility and recognition for projects presented at national innovation competitions.

Figure 1
Factors influencing entrepreneurs' interest in participating in the innovation node.

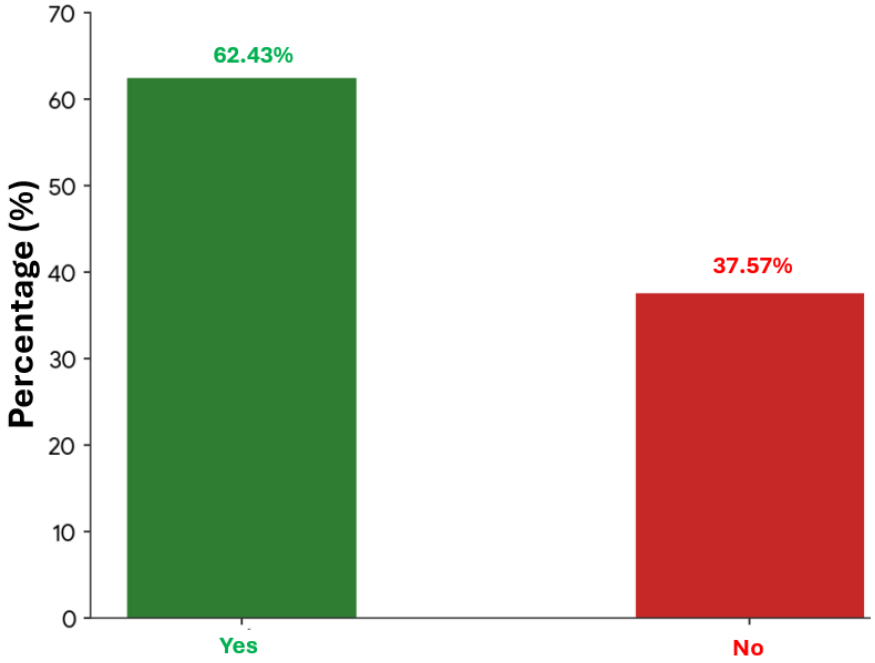


Note: Based on the survey question: *Which factors do you believe would make the innovation node attractive to entrepreneurs?*

Figure 2 illustrates participants' willingness to receive technical and commercial support through the proposed innovation node. Overall, responses indicate a highly favorable attitude toward institutional guidance, with 62.43% of respondents expressing interest in receiving assistance for the commercialization of their products or services. The remaining 37.57% reported no interest in such support. These findings highlight the potential role of the innovation

node as a key institutional mechanism for facilitating technology commercialization and entrepreneurial development.

Figure 2
Participants' willingness to receive commercialization support from the innovation node.



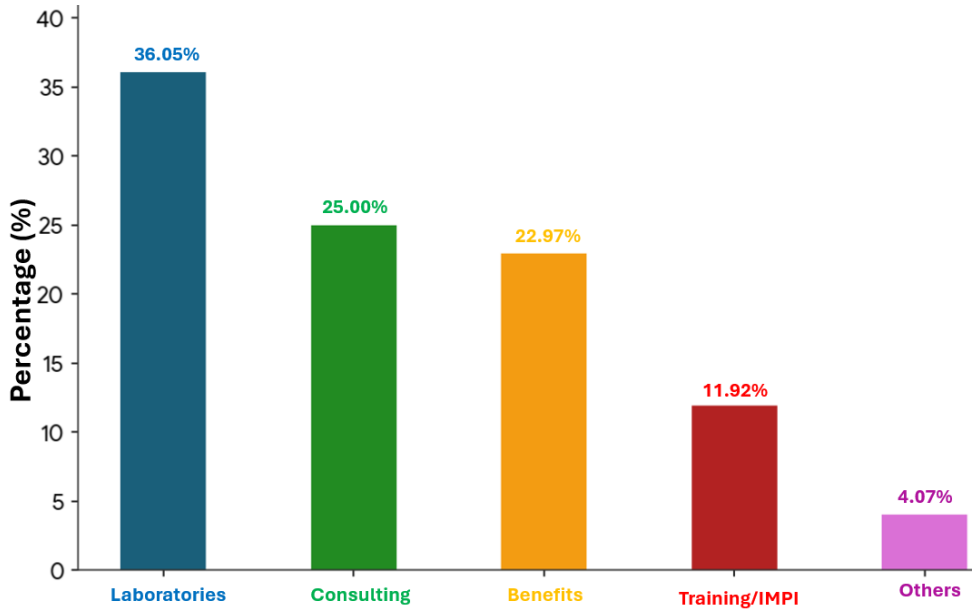
Note: Based on the survey question: *If an innovation node were available, would you be willing to receive guidance to commercialize your product or service?*

The results shown in **Figure 3** identify the infrastructure and support services considered essential for prototype development within the innovation node. Access to well-equipped laboratories was the most frequently identified need (36.05%), reflecting participants' perception that existing facilities often lack the equipment required for advanced technological development. Continuous technical mentoring ranked second (25.00%), underscoring its importance for guiding project development and overcoming technical challenges. Additional institutional benefits accounted for 22.97% of responses, indicating that any complementary support mechanisms are viewed as valuable for strengthening innovation projects.

Although training related to the Mexican Institute of Industrial Property (IMPI) represented a smaller proportion of responses (11.92%), participants emphasized its strategic importance. Many respondents indicated that while they already possess the physical infrastructure needed to develop their prototypes, they lack the procedural knowledge required to protect their innovations through intellectual property mechanisms. Consequently, there is considerable

interest in receiving training on intellectual property management, including through online or hybrid learning formats.

Figure 3
Infrastructure and services required within the innovation node to support prototype development.

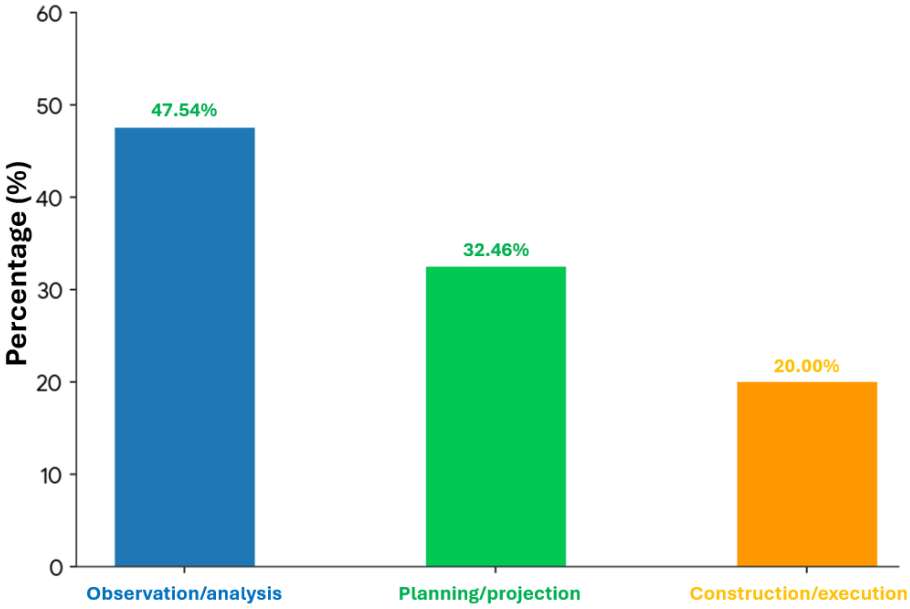


Note: Based on the multiple-choice survey question: *Select the two characteristics that the innovation node should provide to support prototype development.*

The findings presented in **Figure 4** demonstrate that respondents consider a structured innovation methodology essential for the successful development of technology-based projects. The planning and project definition stage received the highest priority (47.54%), highlighting the importance of clearly defining the project's core concept, strategic objectives, and expected scope. The implementation and development phase ranked second (32.46%), reflecting the critical transition from conceptual ideas to functional prototypes or service designs.

Observation and evaluation accounted for 20.00% of responses and were identified as an important component of the innovation process. Participants emphasized the need to systematically assess the novelty and competitive position of their projects in relation to existing market solutions, enabling them to identify their unique value proposition and competitive advantage.

Figure 4
Key methodological components required within the innovation node for project design.

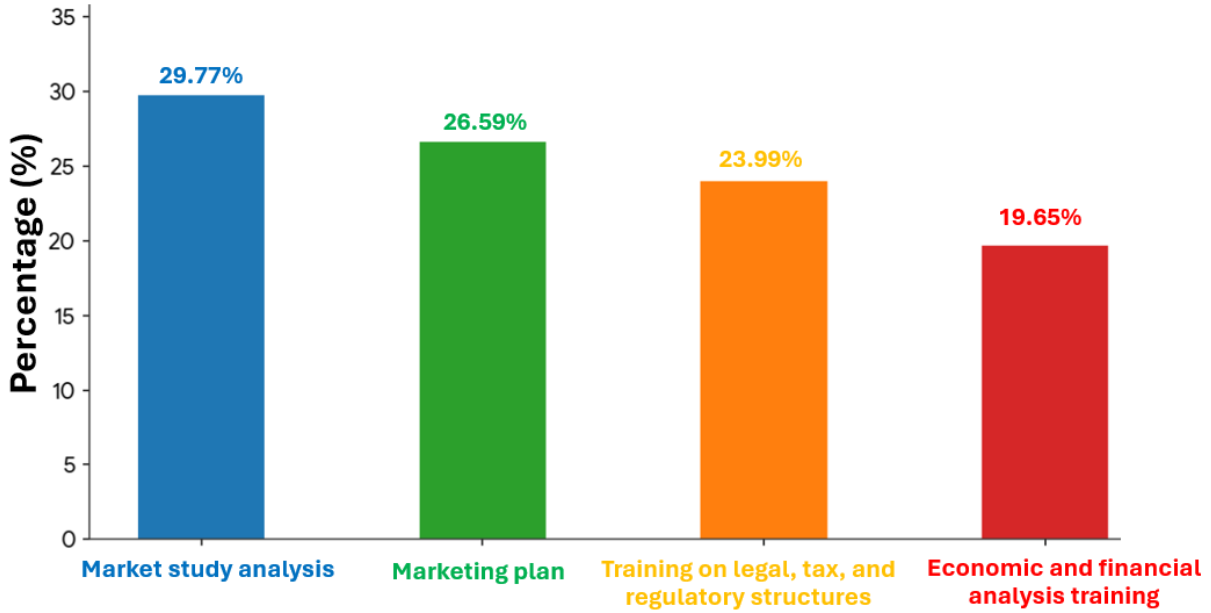


Note: Based on the multiple-choice survey question: *Select the two characteristics that the innovation node should provide to support project design.*

As shown in **Figure 5**, the development of a business model requires support across multiple operational dimensions. The highest priority identified by respondents was training in economic and financial analysis (29.77%), which was considered fundamental for evaluating the technical and commercial feasibility of innovation projects. Market analysis ranked second (26.59%), reflecting the need to identify target markets, understand customer needs, and assess the competitive landscape before launching new products or services.

Participants also highlighted the importance of legal and regulatory guidance (23.99%), particularly regarding business registration, tax compliance, and legal requirements once a technology-based product or service reaches commercialization. Finally, marketing strategy development accounted for 19.65% of responses, emphasizing its role in defining commercialization channels, customer acquisition strategies, and market positioning. Respondents also recognized marketing activities as one of the components requiring the greatest financial investment during business model development.

Figure 5
Essential services required within the innovation node for business model development.



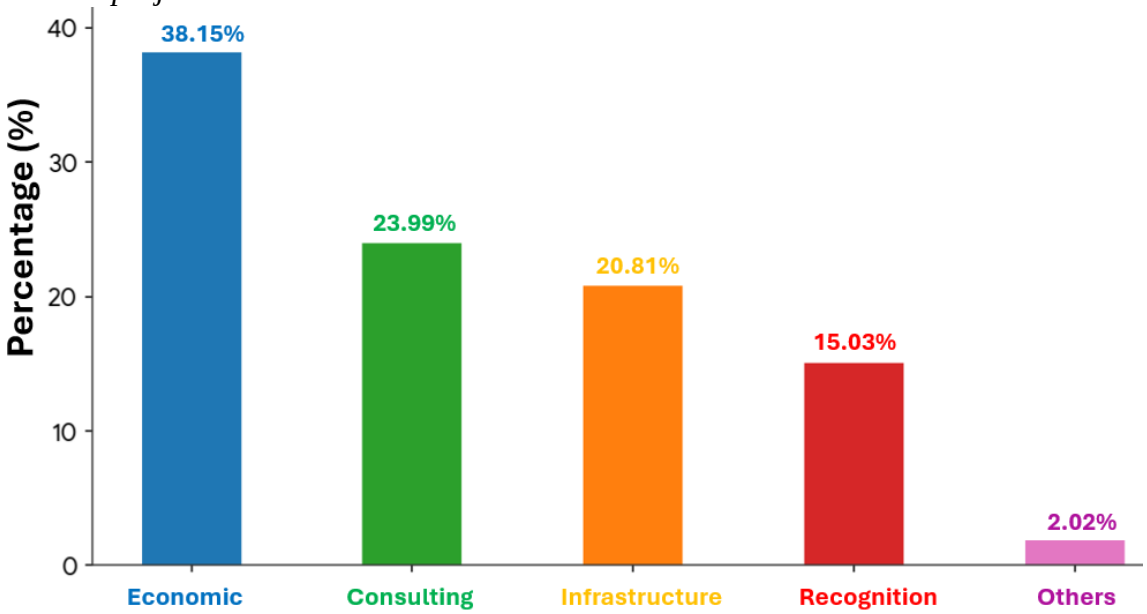
Note: Based on the multiple-choice survey question: *Select the three services that the innovation node should provide to support business model development.*

The results presented in **Figure 6** summarize the institutional resources that participants consider most important for strengthening research and innovation projects. Financial support emerged as the highest priority (38.15%), reflecting the fact that students frequently cover development costs using their own financial resources. Continuous mentoring ranked second (23.99%), reinforcing the importance of sustained technical guidance and technology transfer support throughout the innovation process.

Specialized infrastructure represented 20.81% of responses, with participants emphasizing that limited access to laboratories—particularly those equipped for advanced manufacturing and technical development—restricts the technological advancement of projects at some institutions. Finally, institutional recognition accounted for 15.03% of responses, while other factors represented 2.02%. These findings suggest that institutional recognition is not only symbolic but also an important motivational factor influencing students' commitment to long-term research and innovation activities.

Figure 6

Institutional resources considered necessary to support the development and consolidation of innovation projects.



Note: Based on the survey question: *Which resources would you like your institution to provide to support the development of your project?*

Discussion

The findings indicate that establishing an innovation node at the ITP addresses needs explicitly identified by students and faculty members who participated in the national stage of the 2023 InnovaTecNM competition. The high priority assigned to funding and specialized mentoring suggests that the main barriers to knowledge and technology transfer extend beyond the generation of innovative ideas and are closely associated with access to financial resources and institutional support mechanisms. These findings are consistent with Siegel et al. (2003), who argue that successful technology transfer depends on institutional arrangements capable of facilitating interactions among researchers, industry partners, and innovation managers. Likewise, the Triple Helix framework proposed by Etzkowitz and Leydesdorff (2000) emphasizes that universities play a central role in innovation ecosystems when they establish organizational structures that promote collaboration with industry and government.

The strong willingness of participants to receive technical and commercialization support further reinforces the need for a specialized institutional structure dedicated to innovation. This finding supports the assumptions of the Triple Helix model, which views collaboration among universities, industry, and government as a fundamental driver of knowledge

commercialization and socio-economic development (Etzkowitz & Leydesdorff, 2000). Within this context, an innovation node could serve as an institutional intermediary connecting technology developers with external stakeholders, thereby reducing the persistent gap between academic research and market applications.

The high demand for specialized laboratories and continuous technical mentoring also suggests that physical infrastructure alone is insufficient to support successful innovation processes. Rather, it should be complemented by high-value services that facilitate technological development and commercialization. Participants' interest in intellectual property training indicates that many researchers and entrepreneurs recognize the importance of securing legal protection before introducing their innovations to the market. This observation is consistent with recommendations from the World Intellectual Property Organization (WIPO, 2023), which identifies strategic intellectual property management as a key factor in enhancing the economic value of technological innovations and promoting their transfer to industry.

The demand for specialized laboratories infrastructure can also be understood considering the nature of the scientific research conducted within TecNM. Research lines in nanotechnology and semiconductor materials frequently involve sophisticated fabrication techniques, including ultrasonic spray pyrolysis (Flores-Carrasco et al., 2017), thermal evaporation (Mora et al., 2024), and the polyol synthesis route (Flores-Carrasco et al., 2025), among others. These processes require advanced laboratory facilities, precise experimental control, and specialized equipment to ensure material reproducibility and support subsequent technology scale-up. Consequently, integrating such infrastructure into an innovation node would not only strengthen experimental research capabilities but also facilitate technology validation, intellectual property protection, and eventual commercialization, thereby narrowing the gap between scientific discovery and industrial application.

The results also reveal that respondents assign greater importance to strategic planning, technical implementation, and market analysis throughout the innovation process. This pattern suggests an increasing awareness that successful innovation depends not only on scientific and technical expertise but also on capabilities related to business development, financial planning, and market intelligence. In this regard, Osterwalder and Pigneur (2010) argue that the development of a robust business model is essential for transforming technological innovations

into sustainable value propositions. Similarly, Blank and Dorf (2020) emphasize that early customer validation and continuous experimentation substantially increase the likelihood of success for technology-based ventures by reducing uncertainty during product development.

Finally, the prominence of funding, infrastructure, and specialized mentoring as the most important institutional needs highlights that strengthening the university innovation ecosystem requires a comprehensive strategy integrating financial resources, physical infrastructure, human capital, and effective collaboration mechanisms. Although institutional recognition received comparatively fewer responses, it should not be overlooked, as it may positively influence researchers' motivation, team continuity, and long-term engagement in innovation activities. Overall, these findings provide empirical support for establishing an innovation node in the ITP as an institutional mechanism capable of integrating scientific, technological, and entrepreneurial capabilities. Such a structure has the potential to strengthen knowledge and technology transfer, increase the technology readiness of research projects, and contribute to regional economic development through the creation and growth of technology-based enterprises.

Conclusions

The findings of this study indicate that establishing an innovation node at the ITP represents a relevant institutional strategy for strengthening knowledge and technology transfer. The primary needs identified by students and faculty members include access to funding, specialized technical mentoring, adequate research infrastructure, and training in intellectual property management and business model development. Together, these elements are essential for increasing the technology readiness of innovation projects and enhancing their potential for commercialization.

The strong willingness of participants to receive technical and entrepreneurial support further highlights the need for an institutional structure capable of integrating financial resources, specialized services, and collaborative mechanisms with industry. In this regard, an innovation node has the potential to facilitate the transition of academic prototypes into market-ready products and services, thereby strengthening the innovation ecosystem within the TecNM.

This study has certain limitations. The analysis was based exclusively on students and faculty members whose projects reached the national stage of the 2023 InnovaTecNM competition. Consequently, future research should expand the study population to include participants from a broader range of institutions and innovation programs. Longitudinal studies would also provide valuable evidence for assessing the impact of an innovation node on technology transfer, intellectual property generation and protection, technology commercialization, and the creation of technology-based enterprises.

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Declarations

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